105

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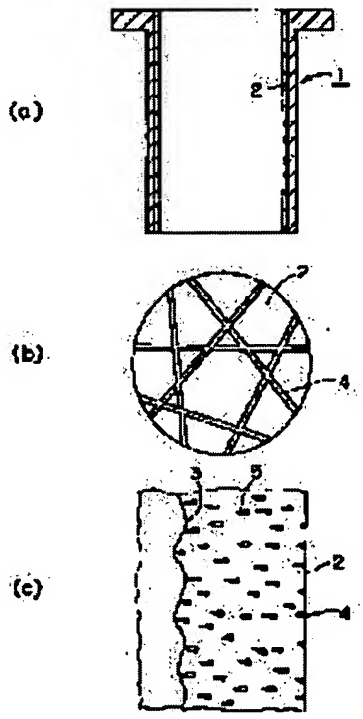
(54) SLIDING MEMBER AND ITS PRODUCTION

(57)Abstract:

PROBLEM TO BE SOLVED: To produce a sliding member having a hard Cr plating layer capable of sufficiently maintaining seizing resistance and wear resistance even if the wear of the sliding face progresses.

SOLUTION: The surface of the base metal in the inner circumferential face of a cylinder liner 1 is formed into a rugged face 3 having surface roughness of 5 to 30μm amplitude and 20 to 100μm pitch, and a hard Cr plating layer 2 is formed on the rugged face 3. The hard Cr plating layer 2 has a reticulately stretching fine recessed part 4 on the surface and furthermore having fine voids 5 reticulately stretching along the rugged face 3 of the base metal surface and distributed independently in the thickness direction on the inside.



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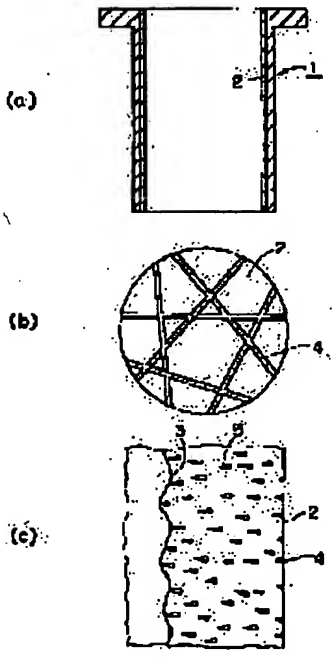

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* NOTICES *

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CLAIMS

[Claim(s)]
[Claim 1] The slide member characterized by distributing and forming in the interior of said hard Cr plating layer the detailed cavity which is in the thickness direction independently in the slide member which has a hard Cr plating layer in a sliding surface, and by which the detailed crevice is formed in the front face of this hard Cr plating layer.
[Claim 2] The slide member according to claim 1 to which the rate of cavernous surface ratio in the cross section of said hard Cr plating layer is characterized by being 5 - 30%.
[Claim 3] The slide member according to claim 1 or 2 to which the interface of a base material with said hard Cr plating layer is characterized by having surface roughness with an amplitude [of 5-30 micrometers], and a pitch of 20-100 micrometers.
[Claim 4] The manufacture approach of the slide member which makes surface roughness of a base material the amplitude of 5-30 micrometers, and the pitch of 20-100 micrometers, and is characterized by having the process performed by repeating a hard Cr plating process and an etching process on the front face of the base material using Cr plating bath containing fluorine ion.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention applies [concerning the slide member which has the hard Cr plating layer in the sliding surface] to an internal combustion engine's cylinder liner and the piston ring and is effective.
[0002]
[Description of the Prior Art] Hard Cr plating may be performed to the peripheral face of the piston ring for internal combustion engines, a side face, or the inner skin of a cylinder liner. However, although hard Cr plating has a high degree of hardness, abrasion resistance, and low coefficient of friction, it has a fault with scarce oil retentivity.
[0003] Then, porous Cr plating in which the detailed crevice which functions as a lubrication sump ball was formed on the front face is performed in order to improve printing-proof nature, and it is used especially for the inner skin of a cylinder liner.
[0004] Surface roughness is added to the approach and base material etched by reverse ****** after -Cr plating, and there is a method of making it remain on a plating front face etc. among these detailed formation approaches of a crevice.
[0005] The detailed crevice formed of etching by reverse ****** has extended in the shape of a mesh after hard Cr plating, and the channel type:crevice has extended in the shape of a mesh by the size of the machining allowance in polish processing of an after process (when a machining allowance is smallness).
Pit type: What the crevice is distributing independently (in the adult case [A machining allowance])
INTAMEDI eight type: The two above-mentioned in-between things (when a machining allowance is inside)
It is divided into three **. And according to sliding properties required of a slide member, such as abrasion resistance and printing-proof nature, it is used properly.
[0006]
[Problem(s) to be Solved by the Invention] However, as for the conventional porous Cr plating, a crevice exists only on a front face, and a crevice effective for a sliding property improvement does not exist in the interior of a plating layer. Therefore, if a sliding surface is worn out, a crevice will be lost, and there is inconvenience in which printing-proof nature deteriorates.
[0007] The technical problem of this invention is offering the slide member which has the hard Cr plating layer which can maintain printing-proof nature and abrasion resistance good, even if wear of a sliding surface advances.
[0008]
[Means for Solving the Problem] This invention has a hard Cr plating layer in a sliding surface, and is characterized by distributing and forming in the interior of said hard Cr plating layer the detailed cavity which is in the thickness direction independently in the slide member by which the detailed crevice is formed in the front face of this hard Cr plating layer.

[0009] The rate of cavernous surface ratio in the cross section of said hard Cr plating layer of it being desirable that it is 5 - 30%, and choosing from printing-proof nature and a wear-resistant point in the above-mentioned range according to the sliding property needed (the rate of cavernous surface ratio says the ratio of the gross area of the cavity in the cross section to the area of a cross section.) is good. If the rate of cavernous surface ratio is large, abrasion resistance and printing-proof nature will fall, and if small, printing-proof nature will fall. In the case of a cylinder liner, the range of the more desirable rate of cavernous surface ratio is 10 - 20%.

[0010] As for the interface of a base material with said hard Cr plating layer, it is desirable to have surface roughness with an amplitude [of 5-30 micrometers] and a pitch of 20-100 micrometers. This surface roughness is realizable by a cutting process by turning etc. When the pitch of surface roughness is too small, two or more cavities stop existing in one wave, and a cavity stops equalizing and distributing in the thickness direction. Similarly, even if the amplitude of surface roughness is too small, the effectiveness of equalization does not arise. Moreover, a plating side tends to become smoother than a base material side by leveling of plating. Since the magnitude of the amplitude of a base material side becomes what the last plating side graduated according to this operation as it is less than 20 micrometers, and was approximated to drawing 3 (a), the magnitude of less than 5 micrometers or a pitch is not desirable. If there is disadvantage similarly the polish machining allowance of the last plating side will increase if the magnitude of the amplitude of a base material side exceeds 30 micrometers and the magnitude of a pitch exceeds 100 micrometers, since the part locally approximated to a sliding surface at drawing 3 (a) will arise, it is not desirable. As mentioned above, the above-mentioned range is desirable.

[0011] Using Cr plating bath containing fluorine ion, the above-mentioned slide member repeats a hard Cr plating process and an etching process, performs them, and can be manufactured by carrying out the laminating of the plating. By Cr plating bath containing fluorine ion, if hard Cr plating is further performed after hard Cr plating, the adhesion which was excellent between plating layers can be acquired.

[0012] Since it is formed as mentioned above and the detailed crevice currently formed in the sliding surface functions as a lubrication sump ball, the slide member of this invention has high printing-proof nature in the early stages of an activity. If a sliding front face is worn out, since the cavity from which it is distributed over the interior of a hard Cr plating layer will newly be exposed to a sliding front face and will serve as a crevice, the lubricating oil of optimum dose can always be held to a sliding surface. Therefore, even if wear advances, printing-proof nature and abrasion resistance are maintainable good. Moreover, since the cavity from which it is distributed over the interior of a hard Cr plating layer is in the thickness direction independently, destructive omission of a hard Cr plating layer are controlled.

[0013] In addition, as for the aperture width of the cavity seen from the vertical direction to the sliding surface, it is desirable from the field on reinforcement to be referred to as 2-8 micrometers by the average. This is about 1/2 as compared with the average of the aperture width of the crevice of the conventional porous Cr plating.

[0014] Drawing 3 is a mimetic diagram for making the front face of a base material into the concavo-convex side which has predetermined surface roughness to explain a good reason.

[0015] Drawing 3 (a) shows the case where repeated the hard Cr plating process and the etching process 3 times, and they are performed by the case where the front face of a base material is formed in the flat side.

[0016] The hard Cr plating layer formed at the first hard Cr plating process and etching process has the detailed crevice which has extended in the shape of a mesh on the front face. The cross section is making the letter of the abbreviation for V characters, and is covered in the hard Cr plating layer in which a laminating is carried out by the 2nd hard Cr plating process and the etching process, and this crevice serves as a cavity 5. Similarly, the crevice of the front face of the hard Cr plating layer of a bilayer eye is also covered with the 3rd hard Cr plating process and an etching process, and it becomes a cavity 5 according to them. Thus, the hard Cr plating layer 2 has the detailed crevice 4 which has extended in the shape of a mesh on the front face, and the detailed cavity 5 which has extended in the

shape of a mesh carries out independent distribution of it in the thickness direction, and it is formed in the interior. That is, it gets down in the thickness direction independently, and the cavity 5 formed in the hard Cr plating layer of a bilayer eye and the cavity 5 formed in the layer [third] hard Cr plating layer extend in the shape of a mesh, and the inside of a flat surface respectively parallel to a base material front face is formed.

[0017] Therefore, the aperture width of the crevice exposed to a front face becomes small gradually, and printing-proof nature cannot be uniformly maintained as it will go to the location of the a-a line shown in drawing, a b-b line, and a c-c line, if the front face is worn out.

[0018] On the other hand, drawing 3 (b) makes the front face of a base material the concavo-convex side which has the detailed concavo-convex configuration, and the case where repeated the hard Cr plating process and the etching process 3 times, and they are performed is shown. The hard Cr plating layer 2 has the detailed crevice 4 which has extended in the shape of a mesh on the front face, and has the detailed cavity 5 from which it has extended in the shape of a mesh along the concavo-convex field on the front face of a base material inside, and is independently distributed in the thickness direction.

[0019] Since the cavity 5 which has extended in the shape of a mesh is formed along the concavo-convex field on the front face of a base material when the base material front face is formed in the detailed concavo-convex field, it is not formed in a flat surface but is formed in the thickness direction in the shape of a wave. Namely, it gets down in the thickness direction independently, and the cavity 5 formed in the hard Cr plating layer of a bilayer eye and the cavity 5 formed in the layer [third] hard Cr plating layer extend in the shape of a mesh along the concavo-convex field on the front face of a base material, respectively, and is formed in the thickness direction in the shape of a wave.

[0020] Therefore, when a front face carries out sequential wear to the location of the a-a line shown in drawing, a b-b line, and a c-c line, the aperture width and the consistency of a crevice which are exposed to a front face are equalized in each location of the thickness direction, and the crevice exposed to a front face becomes that in which the channel type, the pit type, and the INTAMEDI eight type were intermingled. As mentioned above, printing-proof nature in use is uniformly maintainable.

[0021]

[Embodiment of the Invention] Drawing 1 shows 1 operation gestalt of this invention, and the hard Cr plating layer 2 is formed in the inner skin of a cylinder liner 1. The base material front face of the inner skin of a cylinder liner 1 is formed in the concavo-convex field 3 which has the detailed concavo-convex configuration, and said hard Cr plating layer 2 is formed on this concavo-convex field 3. The hard Cr plating layer 2 has the detailed cavity 5 from which it has extended in the shape of a mesh along the concavo-convex field 3 on the front face of a base material inside, and is independently distributed in the thickness direction while having the detailed crevice 4 which has extended in the shape of a mesh on the front face.

[0022] Said concavo-convex field 3 is a field which has surface roughness with an amplitude [of 5-30 micrometers], and a pitch of 20-100 micrometers, and the rate of cavernous surface ratio in the cross section of said hard Cr plating layer 2 is 10 - 20%.

[0023] Next, the formation approach of the hard Cr plating layer 2 in the inner skin of the above-mentioned cylinder liner 1 is explained.

[0024] (1) The base material front face of the inner skin of the formation cylinder liner 1 of a concavo-convex field is formed in the concavo-convex side which has predetermined surface roughness of a cutting process by turning.

[0025] (2) On the base material front face of the inner skin made into the concavo-convex side which has plating processing predetermined surface roughness, repeat -> polish processing of hard Cr plating -> (hard Cr plating process-etching process) was performed.

[0026] The plating bath presentation of hard Cr plating and the monograph affair of a hard Cr plating process and an etching process are shown below. In addition, the first hard Cr plating is strike plating conditions, it is usually 3 - 10 minutes, and other conditions are the same as the conditions shown below.

[0027] ** The plating bath presentation CrO3 250 g/lH2 SO4 1 g/lH2 SiF6 5 g/l** hard Cr plating

process current density 60 A/dm2 plating bath temperature 50-degree-C plating time amount 10 minute ** etching process current density 50 A/dm2 plating bath temperature 50-degree-C time amount 60 seconds [0028] If 1 cycle of a hard Cr plating process -> etching process is performed on condition that the above, hard Cr plating layer 2A will be formed on the base material front face of inner skin, and the detailed crevice 4 which has extended in the shape of a mesh will be formed in the front face of hard Cr plating layer 2A as shown in drawing 2 (a). In this case, since a crevice 4 is formed along the concavo-convex field 3 on the front face of a base material of inner skin, it is not formed in a flat surface but is formed in the thickness direction in the shape of a wave.

[0029] Furthermore, if a hard Cr plating process -> etching process is performed repeatedly, since the laminating of the hard Cr plating layer 2B will be further carried out on hard Cr plating layer 2A formed at the first process of 1 cycle, the crevice 4 formed in the first hard Cr plating layer 2A is covered with hard Cr plating layer 2B of a bilayer eye, and serves as a cavity 5. Under the present circumstances, since hard Cr plating deposits selectively in a crevice 4, a cavity 5 becomes smaller than a crevice 4, and remains to the first hard Cr plating layer 2A. The same detailed crevice 4 as the first hard Cr plating layer 2A is formed in the front face at hard Cr plating layer 2B of a bilayer eye.

[0030] Hereafter, if a hard Cr plating process -> etching process is performed the number of predetermined times repeatedly, the hard Cr plating layer 2 will be formed by predetermined thickness on the base material front face of inner skin.

[0031] If 1 cycle of a hard Cr plating process -> etching process is performed on condition that the above, since the plating thickness of about 0.01mm can be obtained, in order to obtain the plating thickness of 0.15mm, for example, 15 cycle repeat ****** is good.

[0032] (1) Printing-proof sex test (comparison with this invention and the conventional example) Hereafter, the printing-proof nature of the slide member of this invention explains the printing-proof sex test which shows not deteriorating by wear of a sliding surface compared with the conventional slide member.

[0033] (1) The test piece of the examples 1, 2, and 3 of a comparison which performed test piece usual porous Cr plating, and the test piece of the examples 1, 2, 3, and 4 which have the hard Cr plating layer of this invention were prepared. The base material of a test piece is cast iron for cylinder liners (300 about JIS FC).

[0034] (2) Plating processing (example of a comparison) : the examples 1, 2, and 3 of a comparison were created according to the hard Cr plating process -> etching process -> polish processing process. The plating bath presentation of hard Cr plating and the monograph affair of a hard Cr plating process and an etching process are shown below.

[0035] ** It is the same as Cr plating bath presentation shown with 1 operation gestalt of plating bath presentation aforementioned this invention.

** It is the same as the conditions of the hard Cr plating process shown with 1 operation gestalt of hard Cr plating process aforementioned this invention. However, plating time amount is 3 hours.

** It is the same as the conditions of the etching process shown with 1 operation gestalt of etching process aforementioned this invention.

[0036] : (Example) It is the same as the formation approach of the hard Cr plating layer 2 explained with 1 operation gestalt of said this invention. The surface roughness of a base material of the rate of cavernous surface ratio is amplitude [of 8 micrometers], and pitch 30micrometer 15%.

[0037] (3) Grinding of the hard Cr plating layer of the test-method above-mentioned test piece was carried out by various polish cost from the front face, and the printing-proof sex test was presented.

[0038] The outline of the well-known high planar pressure printing testing machine used for drawing 4 at the printing-proof sex test is shown. The test piece 10 explained above is held by the stator 11, and is pushed against the Rota 12 side by the predetermined load P by the hydraulic system. On the other hand, the phase hand part material slack partner test piece 13 is held by Rota 12, and is rotated by revolution of Rota 12.

[0039] The partner test piece 13 is rotated in such equipment, carrying out oiling of the specified quantity to a sliding surface from the lubrication hole 14 currently formed in the stator 11. The load

made to act on a test piece 10 for every fixed time amount is made to increase gradually, the torque generated by sliding with a test piece 10 and the partner test piece 13 is measured by the torque meter, and it is made to record on a recorder. Generating of a seizure phenomenon raises torque rapidly. Therefore, it is burned, the load which acts on the test piece 10 in case torque goes up rapidly is made into a load, it is burned by the size of this seizure load, and the quality of a property is judged.
[0040] The test condition is as follows.
Rotational speed 8 m/s regularity Load It starts from 20kgf. It increases gradually at a rate of 10 kgf/min. Lubricating oil Gas oil Oil temperature 80 degrees C Partner test piece Cast iron material for the piston rings [0041] (4) The seizure load of each test piece obtained by the printing-proof [test-result] sex test is shown in drawing 5 . A crevice disappears by surface polish of 20 micrometers or more, and, as for the example of a comparison, a printing-proof load falls substantially as shown in drawing 5 . On the other hand, even if an example performs 60-micrometer surface polish, printing-proof nature does not fall.
[0042] (2) Printing-proof sex test (rate of surface ratio of a cavity)
Next, it examined about the effect the rate of surface ratio of the cavity from which it is distributed over the interior of a hard Cr plating layer affects printing-proof nature. The test piece with which this trial was presented is the same as the test piece of an example explained by the above-mentioned printing-proof [(1)] sex test (comparison with this invention and the conventional example). However, the various test pieces with which the rates of surface ratio of a cavity differ were created by changing various etching conditions in the conditions of plating processing. A result is shown in drawing 6 .
[0043] The rate of cavernous surface ratio in the cross section of a hard Cr plating layer is understood that printing-proof nature is good in 5 - 30% of range as shown in drawing 6 . The more desirable range is 10 - 27%.
[0044] (3) Printing-proof sex test (surface roughness of a base material)
Next, the surface roughness of a base material examined about the effect affect printing-proof nature. The test piece with which this trial was presented is the same as the test piece of an example explained by the above-mentioned printing-proof [(1)] sex test (comparison with this invention and the conventional example). However, the various test pieces with which the surface roughness of a base material differs were created by changing various surface roughness on the front face of a base material. A result is shown in drawing 7 .
[0045] That to which 5 micrometers or more and a pitch P (distance of the summit and the summit) adjusted [the amplitude H (height from the bottom of thread to the summit)] the surface roughness on the front face of a base material before hard Cr plating to 20 micrometers or more is understood that printing-proof nature is good as shown in drawing 7 .
[0046] In addition, in this invention, if non-conductive powder with a particle size of 0.5-10 micrometers is mixed in 10 - 50 g/l and plating liquid in order to be stabilized in a hard Cr plating layer and to make it generate a cavity, powder can carry out deposition to the crevice produced by etching, and it can prevent that Cr plating deposits in a crevice at a plating process. as non-conductive powder -- aluminum 2O3, SiC, and Si3 N4 etc. -- it can be used.
[0047]
[Effect of the Invention] As explained above, since the slide member of this invention can maintain printing-proof nature and abrasion resistance good even if it wears it out while in use, the degree of freedom which chooses the partner material which can attain reinforcement of a slide member and is combined with this slide member expands it.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] One operation gestalt of this invention is shown and drawing of longitudinal section in which (a) shows a cylinder liner, the enlarged drawing with which (b) looked at a part of hard Cr plating layer from the direction vertical to inner skin, and (c) are some expanded sectional views of inner skin.
[Drawing 2] It is a mimetic diagram explaining the production process of the hard Cr plating layer formed in the above-mentioned cylinder liner, and (a) shows 1 cycle back of a hard Cr plating process -> etching process, and (b) shows the two-cycle back of this process.
[Drawing 3] It is a mimetic diagram for making the front face of a base material into the concavo-convex side which has predetermined surface roughness to explain a good reason, and (a) shows the case where (b) is formed in the concavo-convex field which has the concavo-convex configuration with the detailed front face of a base material, when the front face of a base material is formed in the flat side.

[Drawing 4] It is the explanatory view of a high planar pressure printing testing machine.
[Drawing 5] It is the graph which shows the test result of the printing-proof nature of this invention and the conventional example.
[Drawing 6] It is the graph which shows the test result of the printing-proof nature at the time of changing the rate of surface ratio of a cavity.
[Drawing 7] (a) is a graph which shows the test result of the printing-proof nature at the time of changing the surface roughness of a base material, and the explanatory view in which (b) shows the amplitude of surface roughness, and (c) are the explanatory views showing the pitch of surface roughness.
[Description of Notations]
1 Cylinder Liner
2 Hard Cr Plating Layer
3 Concavo-convex Side
4 Crevice
5 Cavity
10 Test Piece
11 Stator
12 Rota
13 Partner Test Piece
14 Lubrication Hole

[Translation done.]

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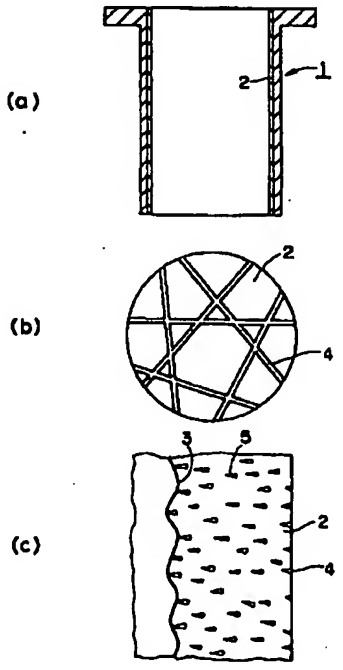
(54)【発明の名称】　摺動部材およびその製造方法

(57)【要約】

【課題】　摺動面の摩耗が進行しても耐焼き付き性、耐摩耗性を良好に維持できる硬質Ｃｒめっき層を有している摺動部材を提供する。

【解決手段】　シリンダライナ１の内周面の母材表面を振幅５～３０μｍ、ピッチ２０～１００μｍの表面粗さを有している凹凸面３に形成し、この凹凸面３上に硬質Ｃｒめっき層２を形成する。硬質Ｃｒめっき層２は、その表面に網目状に延びている微細な凹部４を有しているとともに、内部には母材表面の凹凸面３に沿って網目状に延びており厚さ方向に独立して分布している微細な空洞５を有している。



【特許請求の範囲】
【請求項1】　摺動面に硬質Ｃｒめっき層を有し、この硬質Ｃｒめっき層の表面に微細な凹部が形成されている摺動部材において、
厚さ方向に独立している微細な空洞が前記硬質Ｃｒめっき層の内部に分布して形成されていることを特徴とする摺動部材。
【請求項2】　前記硬質Ｃｒめっき層の断面における空洞面積比率が、5～30%であることを特徴とする請求項1記載の摺動部材。
【請求項3】　前記硬質Ｃｒめっき層との母材の境界面が、振幅5～30μm、ピッチ20～100μmの表面粗さを有していることを特徴とする請求項1または2記載の摺動部材。
【請求項4】　母材の表面粗さを振幅5～30μm、ピッチ20～100μmとし、その母材の表面上に、フッ素イオンを含むＣｒめっき浴を用いて、硬質Ｃｒめっき工程とエッチング工程とを繰り返し行う工程を有していることを特徴とする摺動部材の製造方法。
【発明の詳細な説明】
【0001】
【発明の属する技術分野】本発明は、硬質Ｃｒめっき層を摺動面に有している摺動部材に関し、例えば内燃機関のシリンダライナやピストンリングに適用して有効である。
【0002】
【従来の技術】内燃機関用のピストンリングの外周面、側面、あるいはシリンダライナの内周面に硬質Ｃｒめっきを施すことがある。しかし、硬質Ｃｒめっきは、高硬度、耐摩耗性、低摩擦係数を有するが、保油性が乏しい欠点がある。
【0003】そこで、潤滑油溜まりとして機能する微細な凹部を表面に形成したポーラスＣｒめっきが、耐焼き付き性を改善するために行われており、特にシリンダライナの内周面に利用されている。
【0004】この微細な凹部の形成方法には、
・Ｃｒめっき後、逆電処理でエッチングする方法
・母材に表面粗さを付加し、それをめっき表面に残存させる方法
等がある。
【0005】硬質Ｃｒめっき後、逆電処理によるエッチングによって形成された微細な凹部は網目状に延びており、後工程の研磨加工での加工代の大小により、
チャンネルタイプ：凹部が網目状に延びているもの（加工代が小の場合）
ピットタイプ：凹部が独立して分散しているもの（加工代が大の場合）
インターメディエイトタイプ：上記2つの中間的なもの（加工代が中の場合）
の3つに分けられる。そして摺動部材に要求される耐摩耗性、耐焼き付き性等の摺動特性に応じて、使い分けられている。
【0006】
【発明が解決しようとする課題】しかし、従来のポーラスＣｒめっきは表面にのみ凹部が存在し、摺動特性改善に効果的な凹部はめっき層内部に存在しない。従って、摺動面が摩耗すると凹部が無くなり、耐焼き付き性が劣化する不都合がある。
【0007】本発明の課題は、摺動面の摩耗が進行しても耐焼き付き性、耐摩耗性を良好に維持できる硬質Ｃｒめっき層を有している摺動部材を提供することである。
【0008】
【課題を解決するための手段】本発明は、摺動面に硬質Ｃｒめっき層を有し、この硬質Ｃｒめっき層の表面に微細な凹部が形成されている摺動部材において、厚さ方向に独立している微細な空洞が前記硬質Ｃｒめっき層の内部に分布して形成されていることを特徴とする。
【0009】前記硬質Ｃｒめっき層の断面における空洞面積比率（空洞面積比率は断面の面積に対するその断面における空洞の総面積の比率をいう。）は、耐焼き付き性および耐摩耗性の点から5～30%であるのが望ましく、上記範囲において、必要とされる摺動特性に応じて選択するとよい。空洞面積比率が大きいと耐摩耗性、耐焼き付き性が低下し、小さいと耐焼き付き性が低下する。シリンダライナの場合、より好ましい空洞面積比率の範囲は10～20%である。
【0010】前記硬質Ｃｒめっき層との母材の境界面は、振幅5～30μm、ピッチ20～100μmの表面粗さを有しているのが望ましい。この表面粗さは旋削加工等で実現できる。表面粗さのピッチが小さすぎると、1つのうねりの中に空洞が複数存在しなくなり、空洞が厚さ方向に平均化して分布しなくなる。同様に、表面粗さの振幅が小さすぎても、平均化の効果が生じない。また、めっき面はめっきの平滑化作用により母材面よりも滑らかになる傾向がある。この作用により、母材面の振幅の大きさが5μm未満あるいはピッチの大きさが20μm未満であると、最終めっき面が平滑化し、図3（ａ）に近似したものとなるので好ましくない。同様に、母材面の振幅の大きさが30μmを越えると、最終めっき面の研磨加工代が増大する不利があり、ピッチの大きさが100μmを越えると、摺動面に局部的に図3（ａ）に近似する部分が生じるので好ましくない。以上から上記範囲が望ましい。
【0011】上記の摺動部材は、フッ素イオンを含むＣｒめっき浴を用いて、硬質Ｃｒめっき工程とエッチング工程とを繰り返し行い、めっきを積層することによって製造できる。フッ素イオンを含むＣｒめっき浴によって、硬質Ｃｒめっきの上に更に硬質Ｃｒめっきを施すと、めっき層間に優れた密着性を得ることができる。
【0012】本発明の摺動部材は上記のように形成され

ているので、摺動面に形成されている微細な凹部が潤滑油溜まりとして機能するため、使用初期において耐焼き付き性が高い。摺動表面が摩耗すると、硬質Ｃｒめっき層の内部に分布する空洞が新たに摺動表面に露出して凹部となるため、常に適量の潤滑油を摺動面に保持できる。従って、摩耗が進行しても耐焼き付き性、耐摩耗性を良好に維持できる。また、硬質Ｃｒめっき層の内部に分布する空洞は厚さ方向に独立しているので、硬質Ｃｒめっき層の破壊脱落が抑制される。

【００１３】なお、摺動面に対して垂直な方向から見た空洞の開口幅は、平均値で２～８μｍとするのが、強度上の面から望ましい。これは、従来のポーラスＣｒめっきの凹部の開口幅の平均値と比較すると、約１／２である。

【００１４】図３は、母材の表面を所定の表面粗さを有している凹凸面とするのが良い理由を説明するための模式図である。

【００１５】図３（ａ）は母材の表面が平坦面に形成されている場合で、硬質Ｃｒめっき工程とエッチング工程を３回繰り返して行った場合を示している。

【００１６】最初の硬質Ｃｒめっき工程とエッチング工程で形成された硬質Ｃｒめっき層はその表面に網目状に延びている微細な凹部を有する。この凹部は断面が略Ｖ字状をなしており、２回目の硬質Ｃｒめっき工程とエッチング工程によって積層される硬質Ｃｒめっき層で覆われ、空洞５となる。同様にして、３回目の硬質Ｃｒめっき工程とエッチング工程によって、二層目の硬質Ｃｒめっき層の表面の凹部も覆われて、空洞５となる。このようにして、硬質Ｃｒめっき層２は、その表面に網目状に延びている微細な凹部４を有し、内部には網目状に延びている微細な空洞５が厚さ方向に独立分布して形成される。すなわち、二層目の硬質Ｃｒめっき層に形成された空洞５と三層目の硬質Ｃｒめっき層に形成された空洞５は厚さ方向に独立しており、それぞれ母材表面と平行な平面内を網目状に延びて形成されている。

【００１７】従って、表面が摩耗していくと、図に示すａ－ａ線、ｂ－ｂ線、ｃ－ｃ線の位置にいくに従って、表面に露出する凹部の開口幅が次第に小さくなり、耐焼き付き性を一定に維持できない。

【００１８】これに対して、図３（ｂ）は、母材の表面を微細な凹凸形状を有している凹凸面とし、硬質Ｃｒめっき工程とエッチング工程を３回繰り返して行った場合を示している。硬質Ｃｒめっき層２は、その表面に網目状に延びている微細な凹部４を有し、内部には母材表面の凹凸面に沿って網目状に延びており厚さ方向に独立して分布している微細な空洞５を有している。

【００１９】母材表面が微細な凹凸面に形成されている場合は、網目状に延びている空洞５が母材表面の凹凸面に沿って形成されるため、平面内に形成されず、厚さ方向に波状に形成される。すなわち、二層目の硬質Ｃｒめっき層に形成された空洞５と三層目の硬質Ｃｒめっき層に形成された空洞５は厚さ方向に独立しており、それぞれ母材表面の凹凸面に沿って網目状に延びて、厚さ方向に波状に形成されている。

【００２０】そのため、表面が図に示すａ－ａ線、ｂ－ｂ線、ｃ－ｃ線の位置へ順次摩耗した場合においても、表面に露出する凹部の開口幅と密度は厚さ方向の各位置において平均化し、表面に露出する凹部はチャンネルタイプ、ピットタイプ、インターメディエイトタイプが混在したものになる。以上より、使用中の耐焼き付き性を一定に維持することができる。

【００２１】

【発明の実施の形態】図１は本発明の一実施形態を示しており、シリンダライナ１の内周面に硬質Ｃｒめっき層２が形成されている。シリンダライナ１の内周面の母材表面は微細な凹凸形状を有している凹凸面３に形成されており、この凹凸面３上に、前記硬質Ｃｒめっき層２が形成されている。硬質Ｃｒめっき層２は、その表面に網目状に延びている微細な凹部４を有しているとともに、内部には母材表面の凹凸面３に沿って網目状に延びており厚さ方向に独立して分布している微細な空洞５を有している。

【００２２】前記凹凸面３は振幅５～３０μｍ、ピッチ２０～１００μｍの表面粗さを有している面であり、前記硬質Ｃｒめっき層２の断面における空洞面積比率は１０～２０％である。

【００２３】次に、上記シリンダライナ１の内周面における硬質Ｃｒめっき層２の形成方法について説明する。

【００２４】（１）凹凸面の形成

シリンダライナ１の内周面の母材表面は、旋削加工によって、所定の表面粗さを有する凹凸面に形成される。

【００２５】（２）めっき処理

所定の表面粗さを有する凹凸面とされた内周面の母材表面上に、硬質Ｃｒめっき→（硬質Ｃｒめっき工程－エッチング工程）の繰り返し→研磨加工を行った。

【００２６】硬質Ｃｒめっきのめっき浴組成、および硬質Ｃｒめっき工程とエッチング工程の各条件を下記に示す。なお、最初の硬質Ｃｒめっきは、ストライクめっき条件で、通常３～１０分であり、他の条件は下記に示す条件と同じである。

【００２７】①めっき浴組成

CrO_3	２５０ｇ／ｌ
H_2SO_4	１ｇ／ｌ
H_2SiF_6	５ｇ／ｌ

②硬質Ｃｒめっき工程

電流密度	６０Ａ／ｄｍ²
めっき浴温	５０℃
めっき時間	１０分

③エッチング工程

電流密度	５０Ａ／ｄｍ²

めっき浴温　　50℃
時間　　60秒

【0028】上記の条件で、硬質Crめっき工程→エッチング工程の1サイクルを行うと、図2（a）に示されているように、硬質Crめっき層2Aが内周面の母材表面上に形成され、硬質Crめっき層2Aの表面には網目状に延びている微細な凹部4が形成される。この場合、凹部4は内周面の母材表面の凹凸面3に沿って形成されるため、平面内に形成されず、厚さ方向に波状に形成される。

【0029】更に、硬質Crめっき工程→エッチング工程が繰り返して行われると、最初の1サイクルの工程で形成された硬質Crめっき層2Aの上に更に硬質Crめっき層2Bが積層されるため、最初の硬質Crめっき層2Aに形成された凹部4は二層目の硬質Crめっき層2Bによって覆われて、空洞5となる。この際凹部4には硬質Crめっきが部分的に析出するので、空洞5は凹部4よりも小さくなって最初の硬質Crめっき層2Aに残留する。二層目の硬質Crめっき層2Bには、最初の硬質Crめっき層2Aと同様の微細な凹部4が表面に形成されている。

【0030】以下、硬質Crめっき工程→エッチング工程が所定回数、繰り返して行われると、内周面の母材表面上に所定厚さで硬質Crめっき層2が形成される。

【0031】上記の条件で、硬質Crめっき工程→エッチング工程の1サイクルを行うと、0．01mm程度のめっき厚さを得ることができるので、例えば0．15mmのめっき厚さを得るには、15サイクル繰り返し行えばよい。

【0032】（1）耐焼き付き性試験（本発明と従来例との比較）

以下、本発明の摺動部材の耐焼き付き性が、従来の摺動部材に比べて、摺動面の摩耗によって劣化しないことを示す耐焼き付き性試験について説明する。

【0033】（1）試験片

通常のボーラスCrめっきを施した比較例1，2，3の試験片と、本発明の硬質Crめっき層を有している実施例1，2，3，4の試験片を用意した。試験片の母材は、シリンダライナ用鋳鉄（JIS　FC300相当）である。

【0034】（2）めっき処理

（比較例）：比較例1，2，3は硬質Crめっき工程→エッチング工程→研磨加工工程によって作成した。硬質Crめっきのめっき浴組成、および硬質Crめっき工程とエッチング工程の各条件を下記に示す。

【0035】①めっき浴組成

前記本発明の一実施形態で示したCrめっき浴組成と同じ。

②硬質Crめっき工程

前記本発明の一実施形態で示した硬質Crめっき工程の条件と同じ。ただし、めっき時間が3時間。

③エッチング工程

前記本発明の一実施形態で示したエッチング工程の条件と同じ。

【0036】（実施例）：前記本発明の一実施形態で説明した硬質Crめっき層2の形成方法と同じ。空洞面積比率は15%、母材の表面粗さは振幅8μm、ピッチ30μmである。

【0037】（3）試験方法

上記試験片の硬質Crめっき層を表面から種々の研磨代で研削して、耐焼き付き性試験に供した。

【0038】図4に耐焼き付き性試験に使用した公知の高面圧焼き付き試験機の概要を示す。上記で説明した試験片10は、ステータ11により保持され、油圧装置により所定荷重Pでロータ12側に押し付けられる。一方、相手部材たる相手試験片13は、ロータ12により保持され、ロータ12の回転により回転させられる。

【0039】このような装置において、ステータ11に形成されている注油孔14から摺動面に所定量の給油をしながら、相手試験片13を回転させる。一定時間毎に試験片10に作用させる荷重を段階的に増加させ、試験片10と相手試験片13との摺動により発生するトルクをトルクメータで測定し、記録計に記録させる。焼き付き現象が発生するとトルクが急激に上昇する。したがって、トルクが急激に上昇するときの試験片10に作用する荷重を焼き付き荷重とし、この焼き付き荷重の大小で焼き付き特性の良否を判定する。

【0040】試験条件は次の通りである。

回転速度　　8m／s一定
荷重　　20kgfより開始
　　10kgf／minの割合で段階的に増加
潤滑油　　軽油
油温　　80℃
相手試験片　　ピストンリング用鋳鉄材

【0041】（4）試験結果

耐焼き付き性試験で得られた各試験片の焼き付き荷重を図5に示す。図5に示されているように、比較例は20μm以上の表面研磨により凹部が消滅して、耐焼き付き荷重が大幅に低下する。これに対して、実施例は60μmの表面研磨を行っても、耐焼き付き性が低下しない。

【0042】（2）耐焼き付き性試験（空洞の面積比率）

次に、硬質Crめっき層の内部に分布する空洞の面積比率が耐焼き付き性に及ぼす影響について試験を行った。

この試験に供した試験片は、上記（１）耐焼き付き性試験（本発明と従来例との比較）で説明した実施例の試験片と同じである。ただし、めっき処理の条件におけるエッチング条件を種々変えることによって、空洞の面積比率が異なる種々の試験片を作成した。結果を図６に示す。

【００４３】図６に示されているように、硬質Ｃｒめっき層の断面における空洞面積比率は５～３０％の範囲で耐焼き付き性が良好であることがわかる。より好ましい範囲は１０～２７％である。

【００４４】（３）耐焼き付き性試験（母材の表面粗さ）

次に、母材の表面粗さが耐焼き付き性に及ぼす影響について試験を行った。この試験に供した試験片は、上記（１）耐焼き付き性試験（本発明と従来例との比較）で説明した実施例の試験片と同じである。ただし、母材表面の表面粗さを種々変えることによって、母材の表面粗さが異なる種々の試験片を作成した。結果を図７に示す。

【００４５】図７に示されているように、硬質Ｃｒめっき前の母材表面の表面粗さを振幅Ｈ（谷底から山頂までの高さ）が５μｍ以上、ピッチＰ（山頂と山頂との距離）が２０μｍ以上に調整したものは、耐焼き付き性が良好であることがわかる。

【００４６】なお、本発明において、硬質Ｃｒめっき層に空洞を安定して生成させるために、粒径０．５～１０μｍの非導電性粉末を１０～５０ｇ／ｌ、めっき液に混合すると、エッチングによって生じた凹部に粉末が沈着し、めっき工程で凹部にＣｒめっきが析出してしまうことを防止することができる。非導電性粉末としては、例えばAl_2O_3，ＳｉＣ，Si_3N_4等を使用することができる。

【００４７】

【発明の効果】以上説明したように、本発明の摺動部材は、使用中に摩耗しても耐焼き付き性、耐摩耗性を良好に維持できるので、摺動部材の長寿命化を図ることができ、また、この摺動部材と組み合わせる相手材を選択する自由度が拡大する。

【図面の簡単な説明】

【図１】本発明の一実施形態を示しており、（ａ）はシリンダライナを示す縦断面図、（ｂ）は硬質Ｃｒめっき層の一部を内周面と垂直な方向から見た拡大図、（ｃ）は内周面の一部の拡大断面図である。

【図２】上記シリンダライナに形成する硬質Ｃｒめっき層の製造工程を説明する模式図であり、（ａ）は硬質Ｃｒめっき工程→エッチング工程の１サイクル後を示し、（ｂ）は同工程の２サイクル後を示す。

【図３】母材の表面を所定の表面粗さを有している凹凸面とするのが良い理由を説明するための模式図であり、（ａ）は母材の表面が平坦面に形成されている場合、（ｂ）は母材の表面が微細な凹凸形状を有している凹凸面に形成されている場合を示す。

【図４】高面圧焼き付き試験機の説明図である。

【図５】本発明と従来例の耐焼き付き性の試験結果を示すグラフである。

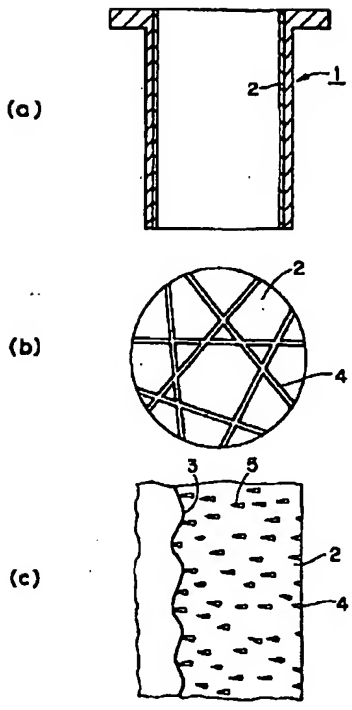
【図６】空洞の面積比率を変えた場合の耐焼き付き性の試験結果を示すグラフである。

【図７】（ａ）は母材の表面粗さを変えた場合の耐焼き付き性の試験結果を示すグラフであり、（ｂ）は表面粗さの振幅を示す説明図、（ｃ）は表面粗さのピッチを示す説明図である。

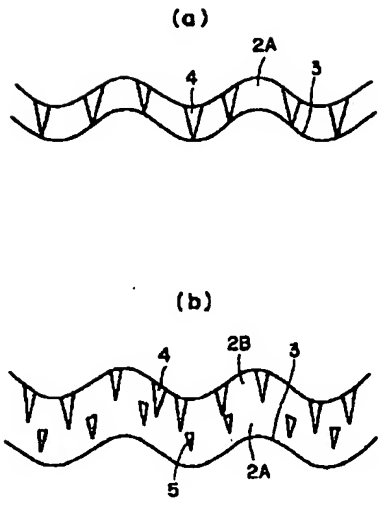
【符号の説明】

１　シリンダライナ
２　硬質Ｃｒめっき層
３　凹凸面
４　凹部
５　空洞
１０　試験片
１１　ステータ
１２　ロータ
１３　相手試験片
１４　注油孔

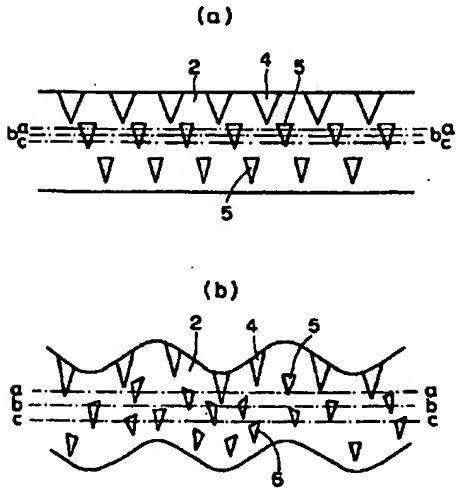
【図1】


(a)
1
2
(b)
2
4
(c)
3
5
2
4

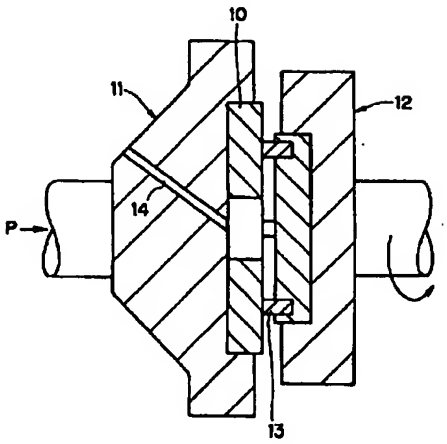
【図2】


(a)
2A
4
3
(b)
4
2B
3
5
2A

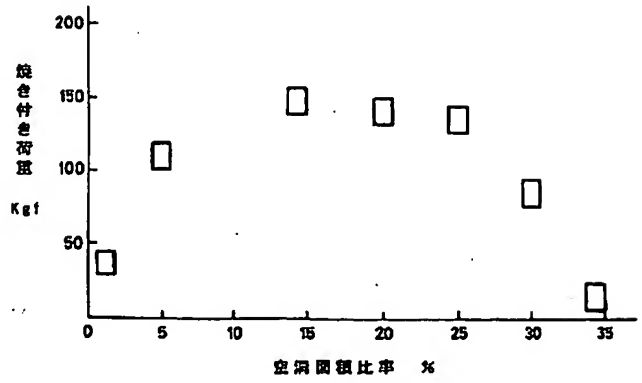
【図3】


(a)
2
4
5
a
b
c
5
(b)
2
4
5
a
b
c
6

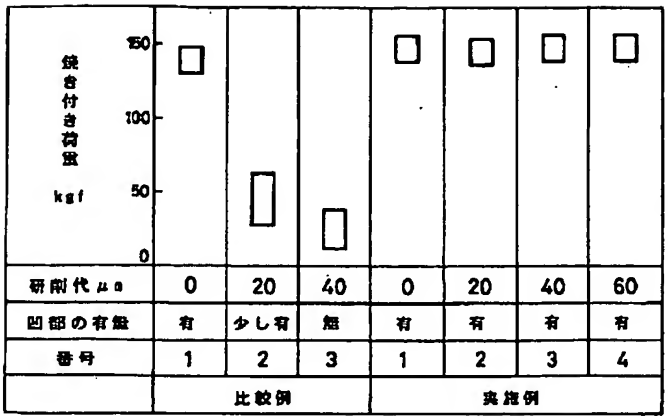
【図4】


10
11
12
14
P
13

【図6】


200
150
100
50
焼き付き荷重
Kgf
0
5
10
15
20
25
30
35
空洞面積比率　%

【図5】



研削代 μm	0	20	40	0	20	40	60
凹部の有無	有	少し有	無	有	有	有	有
番号	1	2	3	1	2	3	4
	比較例			実施例			

【図7】